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EXPERIMENTS IN THE TREATMENT OF RUSTS AFFECTING WHEAT AND OTHER CEREALS.

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INTRODUCTION.

No plant diseases have attracted as widespread attention as the rusts of cereals. For more than a hundred years scientists and practical men all over the world have made these parasites the subject of study and thought, but as yet nothing definite is known as regards a practical and efficient means of preventing them. At the present time the rust of wheat is probably attracting more attention in Australia than any other country. The whole colony is alarmed at the ravages of the rust pest, which, it is estimated, causes a loss of over $10,000,000 annually. At a recent rust conference held in Sydney,* delegates were present from Victoria, South Australia, Queensland, and New South Wales. Some knowledge of what was done at this gathering may be gained when it is stated that it lasted five days and that the report of its proceedings embodies over fifty thousand words. The delegates were a representative body of men, and the report shows them to be thoroughly conversant with nearly all known facts bearing upon this important subject. In this country rust has of late attracted no great amount of attention. This is not due to a diminution in the amount of damage it occasions, but is owing to the fact that the annual drain upon the farmers' income, which it causes, has come to be regarded as a matter of course. Year after year the crop in nearly every field is cut short by rust, so that it is difficult to say just how much damage results simply because there are no figures for comparison.

The average yield of wheat in the United States in 1891 was only 15.3 bushels per acre,† an amount insignificant when compared with some countries that do not have half the natural advantages. This abnormally low yield is, of course, due to several causes, rust being

* A review of the report of this conference is to be found on another page of this JOURNAL.

† Report U. S. Department of Agr., 1891, p. 29.

one of them. By better methods of farming, such as the improvement of varieties, crop rotation, the prevention of rust and smut, proper use of plant foods, etc., the average yield could in all probability be raised to 20 bushels per acre at comparatively little additional expense. Such an increase would mean to our farmers more than $170,000,000, annually. The rust problem, so far as it concerns the yield of grain, probably exerts as great an influence as any one thing over which there is a possibility of control. It is important, therefore, that all phases of the subject be fully investigated as it is by this means only that proper conclusions in regard to prevention can be reached.

PLAN OF THE WORK.

In planning the work on rust it seemed desirable at first to limit the investigations to two lines of research. These may be briefly summarized as follows:

(1) Experiments in spraying with various chemicals and in treating the soil and seed in various ways in the hope of preventing the disease.

(2) Comparative studies of several so-called rust-resisting and non-rust-resisting varieties, to determine whether they possess more or less constant anatomical or physiological characteristics which may explain susceptibility or nonsusceptibility to the disease.

This paper, as the title indicates, will deal with the first problem, *i. e.*, experiments in spraying and in soil and seed treatments to determine their effects on rust. At the outset it was decided to make an attempt to prevent rust without any special regard to expense, it being thought that the latter question could be considered later as a distinct problem. It is proper here to acknowledge the valuable assistance rendered by W. T. Swingle, P. H. Dorsett, and D. G. Fairchild. The experiments would doubtless have been largely under the supervision of Mr. Swingle but for the fact that more immediately important labors called him elsewhere. With but one exception all the treatments at Garrett Park, Md., were made by Mr. Dorsett. He also collected the specimens at each treatment, made the many necessary tedious counts of plants, and harvested and threshed the grain. Mr. Fairchild aided materially in making out the formulæ for fungicides and also assisted in other lines of work.

In order that the work might be carried on under as widely different conditions of soil and climate as possible, Maryland and Kansas were selected as the States in which to make the experiments. In Maryland the work was carried on under the supervision of the writer, while in Kansas a part was intrusted to J. F. Swingle, of Manhattan, and a part to E. Bartholomew, of Rockport, 160 miles northwest of the former place. The experiments at the three stations were in most respects similar, but for the sake of convenience they will be described under separate heads.

Before taking up the experiments in detail, it may be said that they were designed primarily to determine—

(1) The effect on winter wheat of treating the soil with various chemicals before planting.

(2) The effect of treating the seed, previous to planting, with chemicals and with hot water.

(3) The effect of spraying and dusting the plants every ten days from the time they appeared above ground until harvest, using various preparations having known fungicidal value and others that had never been tested in this respect.

(4) The effect of spraying and dusting every twenty days, beginning and ending the same as in (3), and also using the same preparations.

(5) The effect of spraying and dusting the plants every ten days, combined with soil treatment alone and with both soil and seed treatments.

(6) The effect of spraying and dusting every twenty days combined with the other treatments, as in (5).

(7) The effect on spring-planted wheat, oats, and rye of spraying and dusting with various fungicides and other preparations at intervals of two, ten, and twenty days, respectively.

From the foregoing it will be seen that there were soil and seed treatments; spraying and dusting at intervals of two, ten, and twenty days; and a combination of these various methods. In all cases it should be borne in mind that the word "effect" is here used in a broad sense, that is, it includes the influence of the various treatments on rust, as well as on the soil, seed, and plants. The foregoing general summary of the objects of the work will, it is hoped, enable the reader to understand the details which will now be taken up.

EXPERIMENTS AT GARRETT PARK, MARYLAND.

For the work at this place a piece of ground 400 feet long and 110 feet wide was selected. It was comparatively level, and as regards fertility and other necessary important conditions, was fairly even throughout.

On September 20, 1891, the ground was plowed and thoroughly harrowed, but owing to the fact that for several years it had been in clover it was with difficulty put in good condition for planting. On October 5 it was platted, the plats throughout being 3 feet wide and 33 feet long. Walks 2 feet wide were left between each plat, and alleys 3 feet wide were run every 33 feet from end to end of the entire block. Planting began on October 14 and was finished on the 25th of the same month. Every plat was planted by hand, the grain being sown at the rate of 2 bushels per acre in drills 9 inches apart. The drills were opened with a hoe, and after sowing the grain was covered with the same implement. The following is a list of the various treatments, set forth in tabular form.

TABLE 1.—*Statement of the method of treating each plat in the wheat-rust experiments at Garrett Park, Md.*

SERIES I.—SOIL TREATMENT.

Plats.	Kind of treatment.
1 and 91	Untreated.
2 and 92	Soil treated with flowers of sulphur, 4 ounces to each 20 feet of row.
3 and 93	Untreated.
4 and 94	Soil treatment with flowers of sulphur, 2 ounces to each 20 feet of row.
5 and 95	Untreated.
6 and 96	Soil treatment with flowers of sulphur, 1 ounce to each 20 feet of row.
7 and 97	Untreated.
8 and 98	Soil treatment with flowers of sulphur and air-slaked lime, equal parts mixed, 4 ounces to each 20 feet of row.
9 and 99	Untreated.
10 and 100	Soil treatment with flowers of sulphur and air-slaked lime, equal parts mixed, 2 ounces to each 20 feet of row.
11 and 101	Untreated.
12 and 102	Soil treatment with powdered ferrous sulphate, exsiccated, 4 ounces to each 20 feet of row.
13 and 103	Untreated.
14 and 104	Soil treatment with solution of ferrous sulphate, 8 ounces to 1 gallon of water, sprayed on the ground at the rate of ½ gallon to each 20 feet of row.
15 and 105	Untreated.
16 and 106	Soil treatment with ½ gallon of Bordeaux mixture to each 20 feet of row.
17 and 107	Untreated.
18 and 108	Soil treatment with ½ gallon of water containing ½ ounce of potassium sulphide (liver of sulphur) to each 20 feet of row.
19 and 109	Untreated.
20 and 110	Soil treatment with ½ gallon of ammoniacal solution of copper carbonate to each 20 feet of row.
21 and 111	Untreated.
22 and 112	Soil treatment with ½ gallon of Bordeaux mixture to each 20 feet of row.
23 and 113	Untreated.
24 and 114	Soil treatment with a solution of potassium bichromate 1½ ounces in 13½ quarts of water, sprayed on the entire plat.
25 and 115	Untreated.

SERIES II.—SEED TREATED BY IMMERSION.

26 and 116	Seed treatment, immersed for 15 minutes in water at a temperature of 132½° F.
27 and 117	Untreated.
28 and 118	Seed treatment, immersed for 24 hours in an 8:100 solution of copper sulphate, then limed.
29 and 119	Untreated.
30 and 120	Seed treatment, immersed for 24 hours in Bordeaux mixture,
31 and 121	Untreated.
32 and 122	Seed treatment, immersed for 24 hours in potassium bichromate, 5:100 solution.
33 and 123	Untreated.
34 and 124	Seed treatment, immersed for 24 hours in a solution of potassium sulphide (liver of sulphur), 1 ounce to 1 gallon of water.
35 and 125	Untreated.
36 and 126	Seed treatment, immersed for 24 hours in a solution of potassium sulphide (liver of sulphur), ½ ounce to 1 gallon of water.
37 and 127	Untreated.
38 and 128	Seed treatment, immersed for 24 hours in a 1:1000 solution of corrosive sublimate.
39 and 129	Untreated.

SERIES III.—PLANTS SPRAYED AND DUSTED.

40 and 130	Plants sprayed every 10 days, from the time they appeared above ground, with Bordeaux mixture.
41 and 131	Untreated.
42 and 132	Plants sprayed every 10 days, from the time they appeared above ground, with ammoniacal solution of copper carbonate.
43 and 133	Untreated.
44 and 134	Plants sprayed every 10 days, from the time they appeared above ground, with a solution of potassium sulphide, 2 ounces to 3 gallons of water.
45 and 135	Untreated.
46 and 136	Plants sprayed with Bordeaux mixture every 20 days.
47 and 137	Untreated.

TABLE 1.—*Statement of the method of treating each plat in the wheat-rust experiments at Garrett Park, Md.*—Continued.

SERIES III.—PLANTS SPRAYED AND DUSTED—Continued.

Plats.	Kind of treatment.
48 and 138	Plants sprayed every 20 days with ammoniacal solution of copper carbonate.
49 and 139	Untreated.
50 and 140	Plants sprayed every 10 days with cupric ferrocyanide mixture.
51 and 141	Untreated.
52 and 142	Plants sprayed every 10 days with ferrous ferrocyanide mixture.
53 and 143	Untreated.
54 and 144	Plants sprayed every 10 days with copper borate mixture.
55 and 145	Untreated.
56 and 146	Plants sprayed every 10 days with ferric chloride solution.
57 and 147	Untreated.
58 and 148	Plants dusted every 10 days with flowers of sulphur.
59 and 149	Untreated.
60 and 150	Plants dusted every 10 days with sulphosteatite.

SERIES IV.—MISCELLANEOUS TREATMENTS.

61 and 151	Untreated.
62 and 152	Complete treatment with Bordeaux mixture; seed immersed 24 hours; plat sprayed before planting with 13½ quarts and plants sprayed every 10 days.
63 and 153	Untreated.
64 and 154	Complete treatment with potassium sulphide solution, 2 ounces to 2 gallons of water; grounds sprayed and plants sprayed every 10 days.
65 and 155	Untreated.
66 and 156	Seed immersed for 15 minutes in water at 132½° F.; ground sprayed with ammoniacal solution and plants sprayed every 10 days with the same preparation.
67 and 157	Untreated.
68 and 158	Seed immersed for 15 minutes in water at 132½° F.; soil treated with Bordeaux mixture and plants sprayed every 10 days with the same preparation.
69 and 159	Untreated.
70 and 160	Seed immersed for 15 minutes in water at 132½° F.; soil treated with lime and sulphur, equal parts mixed, at the rate of 4 ounces to 20 feet of row.
71 and 161	Untreated.
72 and 162	Seed immersed for 15 minutes in water at 132½° F.; soil treated with ferrous sulphate at the rate of 2 ounces to 20 feet of row.
73 and 163	Untreated.
74 and 164	Seed, soil, and plants treated with ferrous sulphate; seed immersed 24 hours in a 10 : 100 solution; soil sprayed before sowing and plants sprayed every 10 days with 4 ounces to 1 gallon of water.
75 and 165	Untreated.
76 and 166	Seed immersed in ammoniacal solution 24 hours; plants sprayed every 10 days with the same preparation.
77 and 167	Untreated.
78 and 168	Soil treated with common salt at the rate of $\frac{1}{10}$ ounce to 10 feet of row.
79 and 169	Untreated.
80 and 170	Soil treated with salt at the rate of $\frac{1}{20}$ ounce to 20 feet of row.
81 and 171	Untreated.
82 and 172	Soil treated with copper sulphate solution, 13½ ounces to 13½ quarts of water per plat.
83 and 173	Untreated.
84 and 174	Plants sprayed with cupric hydroxide mixture every 10 days.
85 and 175	Untreated.

THE FUNGICIDES AND OTHER PREPARATIONS USED IN SPRAYING AND DUSTING THE PLANTS.

Nine solutions and two powders were used in the spraying and dusting experiments. They were as follows:

(1) Bordeaux mixture.
(2) Ammoniacal solution of copper carbonate.
(3) Ferrous ferrocyanide mixture.
(4) Copper borate mixture.
(5) Ferric chloride solution.

(6) Ferrous sulphate solution.
(7) Cupric ferrocyanide mixture.
(8) Cupric hydroxide mixture.
(9) Potassium sulphide solution.
(10) Flowers of sulphur.
(11) Sulphosteatite powder.

Numbers 1, 2, 5, 6, 9, 10, and 11 were all preparations of more or less known fungicidal value. Numbers 3, 4, 7, and 8, prepared as below described, had, so far as known, never been used in combating parasitic fungi affecting plants.* Below are set forth the formulæ of the various solutions and powders, the amount given in every case being that used per plat at each treatment:

(1) *Bordeaux mixture.*

Cupric sulphate	5.22 grams	0.184 ounce.
Lime (stone)	1.26 grams.	0.044 ounce.
Water	7,572 grams	2 gallons.

The cupric sulphate was dissolved in about a pint of water; the lime was then slaked in a separate vessel, enough water being added afterwards to make a thick whitewash. This was poured into the cupric sulphate solution and enough water added to make 2 gallons. Usually an excess of the lime milk was made up and just enough added to the copper solution to precipitate all of the cupric hydroxide. The presence of copper sulphate in solution, which always indicates an imperfect preparation, was determined by means of a 5 per cent solution of potassium ferrocyanide. A few drops of this solution, when added to the Bordeaux mixture gives a brownish red precipitate if copper sulphate in solution be present. If the reaction has been perfect no change whatever occurs.

(2) *Ammoniacal solution of copper carbonate.*

Copper carbonate	2.34 grams	0.082 ounce.
Aqua ammonia (26°)	50 cc	1.68 ounces.
Water	7,572 grams	2 gallons.

The copper carbonate was first mixed in sufficient water to form a thick paste; the ammonia was then added and the resulting liquid was diluted with 2 gallons of water.

(3) *Ferrous ferrocyanide mixture.*

Ferrous sulphate (exsiccatus)	3.44 grams	0.192 ounce.
Potassium ferrocyanide (yellow prussiate of potash).	9 grams	0.518 ounce.
Water	7,572 grams	2 gallons.

*Lodeman, in Bull. No. 35, N. Y. Cornell Ag. Ex. Sta., used copper borate, but only as a commercial article, suspended in water.

The ferrous sulphate and potassium ferrocyanide were dissolved separately, a pint to a pint and a half of water being used in each case When the two chemicals were completely dissolved they were poured together and enough water added to make 2 gallons. Prepared in this way the solution is of a blue black color.

(4) *Copper borate mixture.*

Cupric sulphate	5.22 grams	0.184 ounce.
Borax (sodium borate)	13.00 grams	0.458 ounce.
Water	7,572 grams	2 gallons.

This solution was prepared in exactly the same way as the last. It was pale blue in color and could scarcely be seen when applied to the leaves of plants.

(5) *Ferric chloride solution.*

Ferric chloride	0.24 gram	0.254 ounce.
Water	7,572 grams	2 gallons.

The ferric chloride was simply mixed with water, the resulting solution being of a deep orange color.

(6) *Ferrous sulphate solution.*

Ferrous sulphate (exsiccatus)	30.42 grams	1.073 ounces.
Water	7,572 grams	2 gallons.

A simple solution made by dissolving the ferrous sulphate in water.

(7) *Cupric ferrocyanide mixture.*

Cupric sulphate	5.22 grams	0.184 ounce.
Potassium ferrocyanide	11.90 grams	0.4197 ounce.
Water	7,572 grams	2 gallons.

The cupric sulphate and potassium ferrocyanide were dissolved separately, each in about a pint and a half of water. When poured together a thick paste-like, chocolate-brown precipitate is formed. This, when diluted with water gives a walnut-brown mixture.

(8) *Cupric hydroxide mixture.*

Cupric sulphate	5.22 grams	0.184 ounce.
Potassium hydrate	2.34 grams	0.082 ounce.
Water	7,572 grams	2 gallons.

This was prepared similarly to Bordeaux mixture, which it resembles somewhat in color and chemical composition.

(9) *Potassium sulphide solution.*

Potassium sulphide (liver of sulphur)	28.34 grams	0.999 ounce.
Water	7,572 grams	2 gallons.

The potassium sulphide was dissolved in the water and sprayed on the plants at once to avoid the chemical change which quickly takes place when the solution is allowed to stand exposed to the air.

(10) *Flowers of sulphur.*

The commercial article was used in the dry form.

(11) *Sulphosteatite.*

This preparation was furnished by C. H. Joosten, of New York. It is a fine greenish powder, consisting of 9 parts of steatite or talc and one part of finely-powdered copper sulphate.

The ammoniacal solution of copper carbonate, containing 2 ounces of copper carbonate dissolved in 1 quart of ammonia and diluted with 22 gallons of water was used as a basis in preparing numbers 1, 2, 4, 7, and 8 of the foregoing. Numbers 3, 5, and 6, containing iron, were double the strength of the copper preparations. As near as possible, therefore, plats treated with preparations 1, 2, 4, 7, and 8 received 1.32 grams of copper at each treatment, while plats treated with 3, 5, and 6 received 2.64 grams of iron. It will be seen that in comparison with the well-known fungicides all the preparations were very weak, the Bordeaux mixture being less than one-fortieth the standard strength.

A preliminary test was made of all the foregoing preparations, with the exception of numbers 10 and 11, to determine (1) their adhesiveness and (2) their power to wet the foliage. By adhesiveness is meant the resistance to removal by rain or dew. Power to wet the foliage really means an even distribution over the entire surface of the leaf. It was found after nearly a month's work on oats, rye, wheat, and barley that no matter in what manner the solutions were applied, with the possible exception of rubbing them on with the hand, none would spread out in a thin film over the leaf surface. When applied with an ordinary improved Vermorel nozzle the liquids would simply strike the leaf and roll off in drops. By using a large atomizer, thereby increasing the fineness of the spray, it was found possible to wet the leaves still more, but the result was far from satisfactory. Various substances, such as glue, gum arabic, molasses, honey, and milk were added to the preparations in the hope that they would increase their wetting properties. Milk was found to be fairly satisfactory, but was discarded on account of expense. None of the other substances proved of value. Finally soap, which at the time we were not aware had before been used, was tried and was found to give better results than anything hitherto employed. After testing various brands, the Ivory soap was selected as the best suited to our wants. It was accordingly used throughout the experiment, combined with all the preparations except ferrous sulphate and ferric chloride solutions; these refused to unite with the soap, and consequently they were applied without it. After a number of trials the following method of using the soap was adopted:

Seven 5-cent bars of Ivory soap were shaved up by means of a small

plane. The shavings were placed in a tin watering can and about 1 gallon of water added. The can was then placed on a small oil stove and slowly heated until the soap was dissolved. When completely dissolved, 1 quart of the liquid, or about one-fourth of the contents of the can, was added to each solution. A complete mixture was affected by pumping the liquid back into itself, using a small hand pump for the purpose. In every case the soap readily mixed with the solutions, forming a frothy, slimy fluid which dispersed itself over the leaf in a fairly satisfactory manner. It may be well at this point to explain why it is so difficult to wet the foliage of wheat, oats, and allied plants. A microscopic examination of the leaves, sheaths, and culms in many cases reveals the fact that they are covered with an exceedingly thin layer of granular wax, which not only prevents the entrance of water to the tissues from without, but also probably acts as a check to transpiration. The wax undoubtedly protects the plants in other ways, but of these and similar questions bearing on the same subject it is unnecessary to speak here.

METHODS OF APPLYING THE LIQUIDS AND POWDERS.

The liquids were all applied with a small double-acting force pump which has been used by the Division for several years in spraying experiments. The pump was provided with a Vermorel nozzle attached to a lance 2½ feet long. The lance in turn was attached to the pump by means of a piece of ¼-inch cloth insertion hose 4 feet long. The solutions were prepared in a 3-gallon bucket and sprayed from it directly upon the plants. With this apparatus a plat, even after the wheat was nearly grown, could be thoroughly sprayed in three minutes. The powders were applied part of the time by hand and part of the time with a small hand bellows. In the soil treatments the fungicide was sprayed or dusted into the bottom of the drills and the seed planted directly upon it.

Having now considered the questions of a general nature connected with the work, the detailed observations made at the time of the various treatments may be taken up.

DETAILED OBSERVATIONS ON THE TREATMENTS.

First treatment (*November 14, 1891*).—The plants at this time were from 2 to 4 inches high and showed no signs of rust or any other disease. In some of the soil and seed treatments the grain had not sprouted. It was decided, however, to make no observations on any of these plats until it was plainly apparent that the seed was killed. A careful examination of all the plats sprayed and dusted revealed the fact that potassium sulphide was the only preparation that had injured the foliage. The tips of the leaves sprayed with this chemical were, in nearly every case, whitened and shriveled. As regards the wetting power of the various preparations it may be stated that the ferrous

ferrocyanide mixture was the only one that gave anything like satisfactory results. It formed a thin film, which covered both sides of the leaves fairly well. The tendency of all the preparations, with the exception of the foregoing, was to collect in drops, and if these attained sufficient size their own weight would cause them to roll from the leaf. The inability to wet the foliage was markedly present in the case of the plats treated with Bordeaux mixture. Ammoniacal solution was somewhat better in this respect, but not so good as the copper borate and cupric ferrocyanide mixtures. Ferric chloride solution did not show on the leaves at all, nor was it possible, except in rare instances, to distinguish the ferrous sulphate on the foliage. Sulphur and sulphosteatite showed plainly at first, but a breath of wind or a little rain or dew was sufficient to remove all traces.

Second treatment (November 25, 1891).—No marked change had taken place in the growth of the plants since the last treatment. Some were beginning to stool and others were just pushing through the soil, showing that the seed was somewhat irregular in germinating. Not a pustule of rust could be found in the experimental block or in any of the fields near by. As regards the wetting properties of the various preparations, little change from what was noted under the first treatment was apparent. All of the liquids were slightly better in this respect, but this was no doubt due to the accumulation from the last spraying. Not a vestige of the first application of sulphur and sulphosteatite could be seen.

Third treatment (December 5, 1891).—At this time all the plats were examined, and in addition to collecting specimens from each, careful notes were made on the injuries, if any, resulting from the various treatments, the adhesiveness of the preparations, and the power each had of wetting the foliage. It was found that in plats 24 and 38, as well as their duplicates, not a grain had started. The first of these received a soil treatment of 13½ ounces of potassium bichromate solution to the plat; the second was a seed treatment, and consisted of immersing the grain twenty-four hours in a 1 : 1000 solution of corrosive sublimate.

Plats 26, 28, 32, 70, 72, and 82 were in very bad condition, not more than 1 per cent of the grain in any case having started. The methods of treating these plats has been given in Table 1. By referring to this it will be seen that in every case where hot water was used the grain either failed entirely to start or else made a very feeble growth. A good opportunity of testing the adhesiveness of the various preparations was offered in consequence of a rainfall of nearly an inch since the last spraying. Ferrous ferrocyanide, cupric ferrocyanide, copper borate, Bordeaux mixture, ammoniacal solution, and cupric hydroxide showed on the foliage in the order named. Ferric chloride and potassium sulphide solution were scarcely visible, and sulphur and sulphosteatite had entirely disappeared. The power of wetting the foliage was constant for each preparation throughout the entire experiment

Given in the order of their efficacy in this respect they are as follows: Ferrous ferrocyanide, copper borate, cupric ferrocyanide, ammoniacal solution, Bordeaux mixture, cupric hydroxide, ferric chloride, and potassium sulphide.

Fourth, fifth, and sixth treatments (December 14 and 23, 1891, and January 4, 1892).—Nothing of importance was noted in the intervals elapsing between these treatments. At the time of the fourth spraying the potassium sulphide and ferrous sulphate solutions were injuring the foliage so badly that it was decided to dilute them to one-half the original strength. One peculiar fact noted in connection with the Bordeaux-sprayed plats was the entire absence of dew from such portions of the leaves as were covered by the preparation. It was thought that this might have an important bearing on the prevention of rust, as the presence of dew is known to be necessary for the infection of the host in the case of many parasitic fungi. Further observation, however, showed that this point was of no importance so far as our work was concerned. It was only possible to make about half of the sixth treatment, as snow began falling soon after spraying commenced and in an hour the plants were completely covered.

Seventh treatment (January 29, 1892).—From January 4 until this date the ground was covered with snow, making it impossible to reach the plants with a spray. Up to this time the most careful search had failed to reveal any trace of rust. The plants had made no growth since the spraying on January 4. With the exception of plats 44, 56, 58, and 60, treated respectively with potassium sulphide solution, ferric chloride solution, sulphur, and sulphosteatite, all the preparations were showing more or less plainly on the foliage. The ferrous ferrocyanide was especially prominent, while cupric ferrocyanide, Bordeaux mixture, and ammoniacal solution followed in this respect in the order named.

Eighth, ninth, tenth, and eleventh treatments (February 9 and 19, March 4 and 14, 1892, respectively).—At the time of each of the foregoing treatments specimens were collected from each plat and careful notes were made on them. However, nothing worthy of recording was ob served.

Twelfth treatment (March 25, 1892).—The weather at this time was quite spring-like and many of the plants were beginning to grow. The duplicate plats were not in as good condition as the others, probably on account of being planted later and not having had an opportunity of getting well started before winter set in. Nothing of special importance was noted at this time.

Thirteenth, fourteenth, and fifteenth treatments (April 5, 16, and 26, 1892).—From March 25 to April 5 the plants made a growth of from 3 to 4 inches. Between the 5th and 16th the weather was quite cool, in consequence of which vegetation remained almost at a standstill. As regards the adhesiveness, wetting power, and injurious effects of

the various solutions, nothing different from what had been previously observed was noted. As yet not a sign of rust had been seen on any of the plants. It was noticed that the plants sprayed with ferrous ferrocyanide, Bordeaux mixture, and ammoniacal solution of copper carbonate were much greener than any of the others. This difference in color of foliage, due to the applications of chemicals in the form of spray, is, however, not peculiar to wheat. It has frequently been seen in the case of similar work upon other crops, but no attempts have been made to explain it.

Sixteenth treatment (May 6, 1892).—On May 1 rust was found on 1 of the untreated plats, a few pustules being seen on the leaves of several stalks arising from one root. It was decided to make no further examination until May 6, the day for the regular treatment. At this time, therefore, every plat was examined and the number of plants showing rust was counted. The rust was noted as being present if only one pustule occurred on a plant. The counting entailed an enormous amount of work, but it was the only way the desired knowledge could be obtained. The plants in all of the original plats averaged at this time from 15 to 18 inches in height, and in most respects were in good condition. Below is given, in tabular form, the results of the count on May 6.

TABLE 2.—*Showing number of plants affected with rust on May 6.*

SERIES I.—SOIL TREATMENT.

Plat.		Method of treating.	No. of plants showing rust.		Total plants showing rust.
Original.	Duplicate.		Original.	Duplicate.	
1	91	Untreated	27	0	27
2	92	Flowers of sulphur, 4 ounces to 20 feet of row	50	40	90
3	93	Untreated	25	0	25
4	94	Flowers of sulphur, 2 ounces to 20 feet of row	40	0	40
5	95	Untreated	0	0	0
6	96	Flowers of sulphur, 1 ounce to 20 feet of row	26	0	26
7	97	Untreated	29	16	45
8	98	Flowers of sulphur and lime, equal parts mixed, 4 ounces to 20 feet of row	21	0	21
9	99	Untreated	0	2	2
10	100	Flowers of sulphur and lime mixed 2 ounces to 20 feet of row	4	0	4
11	101	Untreated	18	0	18
12	102	Ferrous sulphate, 4 ounces to 20 feet of row	15	0	15
13	103	Untreated	31	0	31
14	104	Ferrous sulphate, 8 ounces to 20 feet of row	12	0	12
15	105	Untreated	56	0	56
16	106	Bordeaux mixture, ½ gallon to 20 feet of row	37	0	37
17	107	Untreated	21	0	21
18	108	Potassium sulphide, ½ ounce to ½ gallon of water to 20 feet of row	31	0	31
19	109	Untreated	93	0	93
20	110	Ammoniacal solution, ½ gallon to 20 feet of row	61	0	61
21	111	Untreated	5	0	5
22	112	Bordeaux mixture, ½ gallon to 20 feet of row	7	0	7
23	113	Untreated	1	49	50
24	114	Potassium bichromate, 1½ ounces in 1½ quarts water per plat	dead	dead	.....
25	115	Untreated	47	0	47

TABLE 2.—*Showing number of plants affected with rust on May 6*—Continued.

SERIES II.—SEED TREATED BY IMMERSION.

Plat.		Method of treating.	No. of plants showing rust.		Total plants showing rust.
Original.	Duplicate.		Original.	Duplicate.	
26	116	Water heated to 132½° F., 15 minutes	6	0	6
27	117	Untreated	0	0	0
28	118	Copper sulphate, 24 hours in 8:100 solution	3	0	3
29	119	Untreated	1	0	1
30	120	Bordeaux mixture, 24 hours	21	0	21
31	121	Untreated	20	0	20
32	122	Potassium bichromate, 24 hours, 5:100 solution	0	0	0
33	123	Untreated	3	0	3
34	124	Potassium sulphide, 24 hours, solution containing 1 ounce of potassium sulphide to 1 gallon of water	55	0	55
35	125	Untreated	0	0	0
36	126	Potassium sulphide, 24 hours, solution containing ½ ounce to 1 gallon of water	7	0	7
37	127	Untreated	0	0	0
38	128	Corrosive sublimate, 1:1000 solution, 24 hours	0	0	0
39	129	Untreated	0	0	0

SERIES III.—PLANTS SPRAYED AND DUSTED.

40	130	Bordeaux mixture, every 10 days	0	0	0
41	131	Untreated	42	0	42
42	132	Ammoniacal solution, every 10 days	0	0	0
43	133	Untreated	58	0	58
44	134	Potassium sulphide solution, 1 ounce to 1½ gallons of water, every 10 days	1	0	1
45	135	Untreated	24	0	24
46	136	Bordeaux mixture, every 20 days	2	0	2
47	137	Untreated	0	0	0
48	138	Ammoniacal solution, every 20 days	10	0	10
49	139	Untreated	15	0	15
50	140	Cupric ferrocyanide mixture, every 10 days	8	0	8
51	141	Untreated	25	0	25
52	142	Ferrous ferrocyanide mixture, every 10 days	4	0	4
53	143	Untreated	3	0	3
54	144	Copper borate mixture, every 10 days	0	0	0
55	145	Untreated	37	0	37
56	146	Ferric chloride solution, every 10 days	0	0	0
57	147	Untreated	12	0	12
58	148	Flowers of sulphur, dusted on every 10 days	20	0	20
59	149	Untreated	1	0	1
60	150	Sulphosteatite, dusted on every 10 days	10	0	10

SERIES IV.—MISCELLANEOUS TREATMENTS.

61	151	Untreated	1	0	1
62	152	Seed immersed for 24 hours in Bordeaux mixture, ground sprayed before planting, and plants sprayed every 10 days with same preparation	0	0	0
63	153	Untreated	0	0	0
64	154	Seed immersed 24 hours in potassium sulphide solution, 1 ounce to 1 gallon of water, soil sprayed, and plants sprayed every 10 days with the same preparation	0	0	0
65	155	Untreated	3	0	3
66	156	Seed immersed in hot water 15 minutes, ground sprayed with ammoniacal solution, and plants sprayed with same preparation every 10 days.	0	0	0
67	157	Untreated	8	0	8
68	158	Seed immersed in hot water 15 minutes, soil sprayed with Bordeaux mixture, and plants sprayed with same preparation every 10 days.	0	0	0
69	159	Untreated	65	6	71
70	160	Seed immersed in hot water 15 minutes, soil treated with lime and sulphur, equal parts, 4 ounces to 20 feet of row	0	0	0
71	161	Untreated	83	0	83

TABLE 2.—*Showing number of plants affected with rust on May 6*—Continued.

SERIES IV.—MISCELLANEOUS TREATMENTS—Continued.

Plat.		Method of treating.	No. of plants showing rust.		Total plants showing rust.
Original.	Duplicate.		Original.	Duplicate.	
72	162	Seed immersed 15 minutes in hot water, soil treated with ferrous sulphate, 2 ounces to 20 feet of row	0	0	0
73	163	Untreated	5	0	5
74	164	Seed treated 24 hours in 10:100 solution of ferrous sulphate, soil sprayed with same preparation, plants sprayed every 10 days with 4 ounces to 1 gallon of water	0	0	0
75	165	Untreated	10	0	10
76	166	Seed immersed 24 hours in ammoniacal solution, plants sprayed every 10 days with same preparation	0	0	0
77	167	Untreated	25	0	25
78	168	Soil treated with salt, $\frac{1}{10}$ ounce to 10 feet of row	8	0	8
79	169	Untreated	20	0	20
80	170	Soil treated with salt, $\frac{1}{20}$ ounce to 20 feet of row	35	0	35
81	171	Untreated	17	0	17
82	172	Soil treated with copper sulphate solution, 13½ ounces to 13½ quarts of water per plat	nearly dead.		.....
83	173	Untreated	0	0	0
84	174	Plants sprayed with cupric hydroxide mixture every 10 days	0	0	0
85	175	Untreated	0	0	0

In a study of the foregoing table one of the most striking things noticed is the absence of rust from nearly all the duplicate plats. It should be remembered that all of these were planted from a week to ten days later than the originals; in point of growth they were at least this much behind the latter at the time of the count. The only suggested explanation of lack of rust at this time is upon the assumption that the plants had not reached the proper age for infection. If this be true, as subsequent observations would seem to indicate, the fact has considerable practical value, as it would point to the possible existence of what may be called a susceptible period, at which time a special effort in the way of protecting the plant would be highly important. If such a period really exist the earlier treatments would be of little use and consequently might be abandoned. Looking over the soil treatments, it appears that in no case did they have any appreciable effect on the prevalence of rust. The 12 plats treated gave 304 plants affected, while the untreated showed 354 plants.

In the case of the plats where seed treatments were made, 92 plants were found affected with rust, while the 7 untreated plats used as control gave only 24 plants. The plats sprayed and dusted showed some interesting results. No rust whatever was found on No. 40, sprayed every ten days with Bordeaux mixture, nor could the slightest trace of the fungus be discovered on plat 42, sprayed with ammoniacal solution every ten days. The untreated plats adjoining Nos. 40 and 42 showed, respectively, 42 and 58 affected plants. The plats sprayed with Bordeaux mixture and ammoniacal solution every twenty days were not in as good condition as those where the ten-day treatments were employed. Taking the sprayed and dusted plats as a whole, there was no striking

difference between them and the untreated so far as rust was concerned. Where Bordeaux mixture, ammoniacal solution, ferrous ferrocyanide, and cupric ferrocyanide were used the wheat was certainly much greener and more vigorous than in the untreated plats. In the miscellaneous treatments nothing appears to warrant the assumption that any of them prevented rust.

In searching for the rust an interesting fact was brought out in connection with the distribution and spread of the fungus. In every case the affected plants were found in spots scattered here and there in the plat. Frequently 25 or 30 plants growing together would be found badly rusted, while plants all around would be perfectly free from the disease. Again a single plant in a plat would be found showing perhaps only one affected leaf. Observations made upon these rust areas revealed the fact that they acted as centers of infection, the parasite spreading from them to adjoining plants and thence to other parts of the field.

Examining the weather record for ten days preceding the discovery of rust, we find nothing to warrant the belief that the simultaneous appearance of the fungus the first week in May in widely separated spots was due to peculiar climatic conditions. The weather conditions at this time, so far as relates to temperature and rainfall, were not abnormal, as will be seen by consulting the table given below:

TABLE 3.—*Showing the daily mean temperature and daily precipitation at Garrett Park, Md., from April 20, 1892, to May 20, 1892.*

Date.	Temperature.	Precipitation.
Apr. 20	40	0.85
Apr. 21	44	1.30
Apr. 22	52	0.80
Apr. 23	54	Trace.
Apr. 24	55	.....
Apr. 25	46	.....
Apr. 26	49	.....
Apr. 27	53	.....
Apr. 28	62	.....
Apr. 29	62	0.46
Apr. 30	58	.....
May 1	62	.....
May 2	62	Trace.
May 3	66	.....
May 4	66	.....
May 5	75	.....
May 6	65	.....
May 7	62	.....
May 8	45	.....
May 9	61	Trace.
May 10	50	.....
May 11	64	0.69
May 12	56	.....
May 13	57	.....
May 14	56	0.60
May 15	56	Trace.
May 16	59	.....
May 17	65	.....
May 18	56	1.10
May 19	59	.....
May 20	62	.....

Seventeenth treatment (*May 16, 1892*).—No critical notes were made on the experiment at this time. All plats were sprayed and dusted in the usual way, and from 50 to 100 specimens were collected from each.

It was seen that the rust was spreading rapidly on all the plats except those treated every ten days with Bordeaux mixture, ammoniacal solution, ferrous ferrocyanide, cupric ferrocyanide, and copper borate. As far as could be determined from a superficial examination, the plats sprayed with the two first-named preparations and with ferrous ferrocyanide were wholly free from rust.

Another fungus appeared at this time, and for a while threatened to occasion as much damage as rust. Microscopic examination revealed the fact that this parasite was *Septoria graminum* Desm., a fungus known to occur on many grasses in various parts of the world. The leaves attacked by the *Septoria* show at first brownish elongated spots; these soon run together and eventually the leaf turns yellowish brown and shrivels up. In addition to the foregoing disease it was found that many lower leaves on every plant were turning yellow without the attacks of fungi or parasites of any kind. For a time the yellowing was thought to be a normal appearance due to old age, and to a certain extent this was probably the case. From the fact, however, that the yellowing was largely absent on the parts sprayed with Bordeaux mixture, ammoniacal solution, and ferrous ferrocyanide, it would appear that these treatments, either indirectly by their action on the soil, or directly by exerting some influence on the host, had enabled the first-formed leaves to perform their functions beyond the usual period. The explanation of the phenomenon, however, involves the discussion of physiological questions beyond the province of this paper. The only object in mentioning the matter at this point is to make clear the subsequent notes on the effects of the treatments. In view of the near approach of harvest it was decided to make no further treatments, but the observations were continued at intervals of four to eight days. These will be given under headings the same as in treatments.

Observations on May 24, 25, and 26, 1892.—Preparations were made on May 23 for a critical examination of every plat. A schedule of points to be noted was prepared and this was followed as nearly as possible throughout the examination. The schedule was as follows:

(1) *General condition.*—Under this heading three things were considered, namely, (*a*) size of plants, (*b*) color of plants, and (*c*) number of plants to the plat. On a scale of 100, size was made to count 50 points, color 30 points, and number of plants to the plat 20 points. The standard for size and number of plants to the plat was obtained from plants in an adjoining field. In considering color, the entire absence of yellow leaves, whether due to fungi or other causes, was taken as perfect, in this case giving 30 points.

(2) *Detailed condition.*—In this case six things were considered, namely: (*a*) Size of plants, (*b*) amount of rust, (*c*) amount of *Septoria graminum*, (*d*) amount of other fungi, (*e*) amount of yellow foliage, and (*f*) injury from the treatments. To obtain the size of the plants, measurements were made at three points in each plat and the average taken. It was planned to determine the amount of rust by an actual

count of the affected plants, but this was found to be out of the question, as it would have involved the counting of almost every stalk. When it was found that the rust was so widely distributed, a count of only a few of the more promising looking plats was made. The data on the amount of *Septoria*, yellow foliage, etc., was obtained by carefully examining the plats and marking the results in percentages. It is hardly necessary to give in detail the figures obtained as a result of the foregoing observations. Summarizing the data, it may be stated as follows:

(1) The general condition of all the original plats, with the exception of those treated with Bordeaux mixture, ammoniacal solution of copper carbonate, ferrous ferrocyanide, and copper borate, was the same, averaging 55 to 75 when compared with wheat in the field taken as 100. The poor condition of the wheat, treated as well as untreated, when compared with the ordinary field crop, was due to a number of causes, the most important being the omission of fertilizers in planting and the thinness of the plants due to necessary walks, alleys, etc. The condition of the plats sprayed with Bordeaux mixture, ammoniacal solution of copper carbonate, ferrous ferrocyanide, cupric ferrocyanide, and copper borate averaged 90 to 100, when compared with the field crop.

(2) The general condition of all the duplicate plats was 10 to 20 points lower than the original.

(3) There was no marked difference in the height of the plants in the various plats, the average for the originals being 18 to 30 inches and the duplicates 14 to 24 inches.

(4) The amount of rust on the various plats, as nearly as could be determined, was the same, fully 90 per cent of the plants in every case being affected. An actual count of the rusted plants in 13 plats gave the following results:

TABLE 4.—*Showing actual number of rusted plants on 14 plats.*

Plat.	Method of treating.	Number of plants showing rust.
1	Untreated	1,908
2	Soil treatment with sulphur	2,500
3	Untreated	1,910
4	Soil treatment with sulphur	2,368
5	Untreated	2,196
6	Soil treatment with sulphur	1,741
40	Sprayed with Bordeaux mixture every 10 days	2,716
41	Untreated	2,568
42	Sprayed with ammoniacal solution every 10 days	1,247
44	Sprayed with potassium sulphide solution every 10 days	2,729
46	Sprayed with Bordeaux mixture every 20 days	2,456
48	Sprayed with ammoniacal solution every 20 days	2,672
50	Sprayed with cupric ferrocyanide mixture every 10 days	2,736
52	Sprayed with ferrous ferrocyanide mixture every 10 days	2,548

Each of the foregoing plats contained from 2,600 to 3,400 plants.

(5) *Septoria graminum* occurred upon all the plats, from 5 to 10 per cent of the foliage being affected. It was worse where the plants were thick, and was almost entirely absent where, from the effects of the seed treatments and other causes, the plants were thin. Spraying with

Bordeaux mixture and ammoniacal solution of copper carbonate prevented this fungus to a large extent.

(6) All plants except those sprayed with Bordeaux mixture, ammoniacal solution, and ferrous ferrocyanide, showed from 5 to 20 per cent of yellow foliage. The above exceptions were practically free from the trouble.

(7) The injury to the plants resulting from the work was only marked in the case of the soil and seed treatments. These are referred to in detail in Table 2.

Observations on June 4, 1892.—From May 26 to June 4 rust rapidly increased; in fact, at the latter date not a leaf could be found that did not show the fungus. The lower leaves were in every case the more badly diseased; the rust sori, however, were found in great quantities on the very topmost leaves. All the fields in the neighborhood were badly rusted, in many cases the plants being literally red with the fungus. For the first time the teleutospores were found and upon examination it was seen that they possessed all the characteristics of those belonging to *Puccinia rubigo-vera*. No further field notes were made and on June 9 the crop was harvested. The crop on each plat was cut in the usual manner, after which each bundle was marked with a numbered tag, and shocked after the ordinary fashion. The weight of the straw and grain, weight of grain, and weight of straw were next determined. The straw and grain together were first weighed, then the latter was flailed out and weighed, thus giving the rest of the data. A careful study of these figures reveals so little of interest that it is deemed unnecessary to publish them in full. The yield was fairly even throughout the field, the only striking differences in this respect being where the plants were thin on account of certain seed and soil treatments, the injurious effects of which have already been pointed out. Summing up this phase of the subject, it may be said that so far as affecting the yield, except in the cases noted, the treatments had no appreciable effect.

SUPPLEMENTARY EXPERIMENTS IN THE TREATMENT OF RUST OF WHEAT AND OTHER CEREALS AT GARRETT PARK, MARYLAND.

As a supplementary experiment it was decided early in March, 1892, to spray spring-planted wheat, oats, and rye with a number of the standard fungicides, using full and half strength solutions. It was thought best to plant the grain as late as possible in order to invite the attacks of rust fungi. No harvest of course was expected. On May 17 fifty-seven plats, each 3 by 33 feet, were staked off. Thirty-six plats were planted with wheat, 12 with oats, and 9 with rye. In the case of each crop half of the plats were treated and half were left for control. The fungicides used were Bordeaux mixture, full and half strength, ammoniacal solution, full and half strength, sulphur and sulphosteatite. The Bordeaux mixture, full strength, contained 6 pounds of copper sulphate and 4 pounds of lime to 22 gallons of water. The ammoniacal solution was made by dissolving 2½ ounces

of copper carbonate in 1½ pints of ammonia then diluting to 25 gallons. The sulphur and sulphosteatite were used as described in the experiment with winter wheat, p. 202. The plants were treated at intervals of two, ten, and twenty days, respectively, from the time they appeared above ground until they were 8 inches high. Without going into the details of the work the results may be briefly summarized as follows:

(1) Rust appeared more or less on all the plats when the plants were from 2 to 5 inches high.

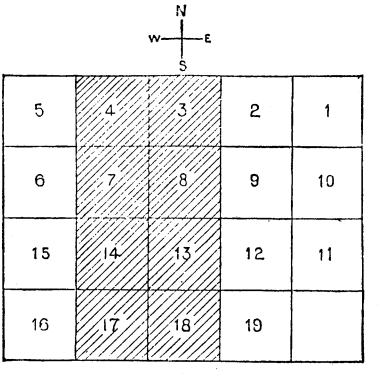
(2) The fungus was more abundant at first on the untreated plats and those dusted with flowers of sulphur and sulphosteatite. Despite the treatment, however, rust increased on every plat, and by the time the plants were 8 inches high there was no difference between the plats as regards the amount of the fungus.

In all cases where the liquids were used, soap was added to make them wet the leaves more thoroughly. It was found, however, exceedingly difficult to cover the foliage even when the sprayings were made every two days. In case of the oft-repeated treatments fully four-fifths of the leaf surface was frequently found wholly unprotected.

EXPERIMENTS AT MANHATTAN, KANS.

Mr. J. F. Swingle, to whom the work at this place was entrusted, conducted the experiments on his farm a mile and a half from the State Agricultural College. Early in September, 1891, Mr. Swingle was requested to select from an average field of wheat a block containing 8,000 to 10,000 square feet. This was done, and on October 13 the ground was platted. Nineteen plats were laid out, each 20 feet square, in 4 rows, extending east and west. The plat in the southeast corner was cut out in order to give the necessary number. The accompanying diagram shows the arrangement of the plats, and the explanation gives the treatment each received:

DIAGRAM 1.—*Showing plan of experiment at Manhattan, Kans.*



EXPLANATION OF DIAGRAM 1.

Plats 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19, untreated.

Plats 2, 8, and 14, sprayed every ten days with Bordeaux mixture, full strength, from the time the plants appeared above ground until harvest.

Plats 4, 10, and 16, sprayed every ten days with ammoniacal solution of copper carbonate, full strength, from the time the plants appeared above ground until harvest.

Plats 6, 12, and 18, sprayed every ten days with potassium sulphide solution, 2 ounces of potassium sulphide to 3 gallons of water, from the time the plants appeared above ground until harvest.

The land was rich bottom, having grown but one previous crop and that in 1891. By an accident a part of the field selected was plowed early in July. This part fortunately almost exactly coincided with plats 3, 4, 7, 8, 13, 14, 17, and 18. Mr. Swingle in commenting upon this point says:

In selecting the field of wheat I did not think of the early plowing a part of it received. This, as will be seen further on, had an important bearing on the yield of straw and grain. It so happened, however, that the lines running north and south and separating the early from the late plowing almost coincided with the lines separating certain plats. In considering the effect of the treatment, therefore, the plats plowed early should be compared with each other and not with those plowed late.

The sprayings were made with a knapsack pump and Vermorel nozzle, beginning on October 17 and ending June 13, no soap being used. On June 21, Mr. Swingle, acting under instructions from the writer, carefully examined the plats and estimated to the best of his ability the amount of rust on each. The figures obtained are set forth in the following table:

TABLE 5.—*Showing the per cent of rust on the treated and untreated plats June 21.*

Plat.	Kind of treatment.	Per cent of plants rusted.
1	Untreated	80
2	Bordeaux mixture	20
3	Untreated	90
4	Ammoniacal solution	95
5	Untreated	70
6	Potassium sulphide	75
7	Untreated	90
8	Bordeaux mixture	10
9	Untreated	70
10	Ammoniacal solution	75
11	Untreated	90
12	Potassium sulphide	40
13	Untreated	100
14	Bordeaux mixture	25
15	Untreated	75
16	Ammoniacal solution	75
17	Untreated	100
18	Potassium sulphide	75
19	Untreated	90

According to the foregoing estimate, the plats sprayed with Bordeaux mixture were much more free from rust than any of the others and potassium sulphide was better than ammoniacal solution. The early plowing did not seem to affect the results at all, so far as rust was concerned. Mr. Swingle was directed to collect material from all the plats and forward it to Washington for examination. This was done, and the

results of a critical study of the material showed that the estimate made in the field, regarding the amount of rust on each plat, was a conservative one. On June 27 and 28 the grain was harvested with a sickle, each plat being trimmed down beforehand to 16½ feet square. Nothing further was done with the grain until August 8, when the straw and grain were weighed and the latter threshed out with a flail.

The result of this work is set forth in the following table:

TABLE 6.—*Showing weight of straw and grain and weight of grain and of straw from each plat.*

Plat.	Kind of treatment.	Weight of straw and grain.	Weight of grain.	Weight of straw.
1	Untreated, late plowing	23	7	15
5	do	23	7	15
2	Bordeaux mixture, late plowing	24	7	16
3	Untreated, early plowing	34	10	24
8	Bordeaux mixture, early plowing	34	11	23
14	do	32	10	22
7	Untreated, early plowing	31	9	21
10	Ammoniacal sol tion, late plowing	28	9	19
11	Untreated, late plowing	17	5	8
4	Ammoniacal solution, early plowing	35	9	25
13	Untreated, early plowing	29	8	20
16	Ammoniacal solution, late plowing	24	8	15
19	Untreated, late plowing	15	5	9
12	Potassium sulphide, late plowing	19	6	13
9	Untreated, late plowing	20	7	13
18	Potassium sulphide, early plowing	33	10	23
15	Untreated, late plowing	20	6	13
6	Potassium sulphide, late plowing	25	7	17
17	Untreated, early plowing	32	9	23

The plats are arranged so as to bring those plowed early and late together, for the sake of more conveniently comparing them. A study of the figures reveals the fact that there are no very striking differences in favor of any of the treatments. Comparing the total yield of plats 8 and 14, sprayed with Bordeaux mixture, plowed early, with the the yield of plats 3 and 13, the nearest untreated plats, plowed early, it is seen that there is an increase of 3 pounds in the total yield and 3 pounds in the yield of grain in favor of the spraying. Plat 2, treated with Bordeaux mixture and plowed late, yielded only 1 pound more straw than plat 1, untreated. Compared with untreated plat 9, however, plat 2 yielded 3 pounds more straw for the same amount of grain. Where the plats were sprayed with the ammoniacal solution, there was an increase in every case of the treated over the untreated; in fact, the difference, between the sprayed and unsprayed plats was here more striking than where Bordeaux mixture was used. It is doubtful, however, if this increase was due to the prevention of rust, for, as shown in Table 5, these plats were almost as badly rusted as the untreated. It is barely possible that the increased yield was due to the fertilizing effect of the ammoniacal solution on the soil. The plats sprayed with potassium sulphide gave about the same amount of increase as those treated with the ammoniacal solution. There is no apparent reason for believing that the increase was due to the prevention of rust. On the other hand, there is some proof that increased fertility of the soil, due to the application of the potassium sulphide,

might have caused the difference noted. Summing up the results of this experiment, it may be said that so far as could be ascertained by a careful examination Bordeaux mixture did, to a considerable extent, prevent rust, but the other preparations had little or no effect on the disease. Furthermore in no case did the prevention of rust affect the yield to any appreciable extent.

EXPERIMENTS AT ROCKPORT, KANS.

Mr. Bartholomew's farm, where the experiments described in the following pages were conducted, is located in Rooks County, latitude 39° 30′ north and longitude 99° 20′ west. Three lines of work were carried on at his place, which may be designated as experiments A, B, and C, respectively.

EXPERIMENT A.

This experiment was, to a certain extent, the same as that conducted with winter wheat at Garrett Park, Md., there being ten kinds of soil treatment, seven of seed treatment, six treatments involving spraying, and six combining all three of the foregoing. The soil selected for the work was rich second bottom, so situated as to render the crops planted upon it peculiarly subject to the attacks of rust fungi. In accordance with instructions from the Department, Mr. Bartholomew early in October, 1891, staked off 132 plats, each 25 feet long and 4½ feet wide. From October 9 to 15 the wheat was planted, the variety known as "Turkey" being used. The grain was all planted in rows 9 inches apart, there being five rows in each plat. Eighteen inches were left between plats to serve as walks. The following is a tabular statement showing the treatment each plat received:

TABLE 7.—*Showing manner of treatment of plats in Experiment A, at Rockport, Kans.*

Plat.	Kind of treatment.
1 and 66	Untreated.
2 and 67	Soil treatment with flowers of sulphur, 5 ounces to 25 feet of row.
3 and 68	Untreated.
4 and 69	Soil treatment with flowers of sulphur, 2½ ounces to 25 feet of row.
5 and 70	Untreated.
6 and 71	Soil treatment with flowers of sulphur, 1¼ ounces to 25 feet of row.
7 and 72	Untreated.
8 and 73	Soil treatment with lime and sulphur, equal parts mixed, 5 ounces to 25 feet of row.
9 and 74	Untreated.
10 and 75	Soil treatment with lime and sulphur, equal parts mixed, 2½ ounces to 25 feet of row.
11 and 76	Untreated.
12 and 77	Soil treatment with powdered exsiccated ferrous sulphate, 5 ounces to 25 feet of row.
13 and 78	Untreated.
14 and 79	Soil treatment with 5 pints of water containing 5 ounces exsiccated ferrous sulphate to 25 feet of row.
15 and 80	Untreated.
16 and 81	Soil treatment with Bordeaux mixture, 5 pints to 25 feet of row.
17 and 82	Untreated.
18 and 83	Soil treatment with 5 pints of water containing 1¼ ounces potassium sulphide to 25 feet of row.
19 and 84	Untreated.
20 and 85	Soil treatment with 5 pints of ammoniacal solution of copper carbonate to 25 feet of row.
21 and 86	Untreated.
22 and 87	Seed immersed in water at 133° F. for 15 minutes.
23 and 88	Untreated.
24 and 89	Seed immersed in an 8:100 solution of copper sulphate for 24 hours, then limed.
25 and 90	Untreated.
26 and 91	Seed immersed for 24 hours in Bordeaux mixture.
27 and 92	Untreated.
28 and 93	Seed immersed for 24 hours in a 5:100 solution of potassium bichromate.
29 and 94	Untreated.

TABLE 7.—*Showing manner of treatment of plats in Experiment A, at Rockport, Kans.*—Continued.

Plat.	Kind of treatment.
30 and 95	Seed immersed for 24 hours in a solution of potassium sulphide, 1 ounce to 1 gallon of water.
31 and 96	Untreated.
32 and 97	Seed immersed for 24 hours in a solution of potassium sulphide, ½ ounce to 1 gallon of water.
32½ and 98	Untreated.
33 and 99	Untreated.
34 and 100	Seed immersed for 24 hours in a 1:1000 solution of corrosive sublimate.
35 and 101	Untreated.
36 and 102	Plants sprayed every 10 days with Bordeaux mixture.
37 and 103	Untreated.
38 and 104	Plants sprayed every 10 days with ammoniacal solution of copper carbonate.
39 and 105	Untreated.
40 and 106	Plants sprayed every 10 days with potassium sulphide solution, 2 ounces to 3 gallons of water.
41 and 107	Untreated.
42 and 108	Plants sprayed with Bordeaux mixture every 20 days.
43 and 109	Untreated.
44 and 110	Plants sprayed with ammoniacal solution of copper carbonate every 20 days.
45 and 111	Untreated.
46 and 112	Plants sprayed with potassium sulphide solution, 2 ounces to 3 gallons of water every 20 days.
47 and 113	Untreated.
48 and 114	Seed, soil, and spraying treatments. Seed immersed in Bordeaux mixture 24 hours; soil treated with 5 pints of Bordeaux mixture to 25 feet of row; plants sprayed with Bordeaux mixture every 10 days.
49 and 115	Untreated.
50 and 116	Seed, soil, and spraying treatments, with potassium sulphide solution, 2 ounces to 3 gallons of water. Seed immersed for 24 hours; soil treated with 5 pints to 25 feet of row; plants sprayed every 10 days.
51 and 117	Untreated.
52 and 118	Seed, soil, and spraying treatments. Seed immersed for 24 hours in ammoniacal solution of copper carbonate plants sprayed every 10 days with the same preparation.
53 and 119	Untreated.
54 and 120	Seed and spraying treatments. Seed immersed for 15 minutes in water at 133° F.; plants sprayed every 10 days with Bordeaux mixture.
55 and 121	Untreated.
56 and 122	Seed and soil treatment. Seed immersed for 15 minutes in water at 133° F.; soil treated with lime and sulphur equal parts, 5 ounces to 25 feet of row.
57 and 123	Untreated.
58 and 124	Seed and soil treatment. Seed immersed in water at 133° F. for 15 minutes; soil treated with 2½ ounces ferrous sulphate to 25 feet of row.
59 and 125 60 and 126 61 and 127 62 and 128 63 and 129 64 and 130 65 and 131	Reserved for spring treatment.

The Bordeaux mixture and ammoniacal solution used throughout the foregoing experiment were full strength, *i. e.*, containing, respectively, 6 pounds of copper and 4 pounds of lime to 22 gallons of water, and 3 ounces of copper basic carbonate dissolved in 1½ pints of ammonia to 22 gallons of water. Soap was not used with any of the preparations. All of the soil and seed treatments were made before the grain was planted. Spraying began on October 28, and with the exception of three interruptions caused by cold weather and snow, was continued at the regular ten and twenty-day intervals until harvest. No rust appeared until May 24, but from this time on it increased very rapidly, every plat in the entire tract being attacked to a greater or less extent. Upon examination the fungus proved to be *Puccinia rubigo-vera*, the common species of western Kansas. In accordance with directions from the Department, Mr. Bartholomew made careful notes on the

various plats with respect to the effects of the treatments on rusts and other fungi. After harvesting, the total yield of straw and grain, the yield of straw, and the yield of grain were each ascertained. From this data the following notes on the general effect of the treatment on each plat were prepared by Mr. Bartholomew:

Plats 1 and 66.—Untreated. These were so near like all other untreated plats that their condition may be taken as a standard. Three fungi were noted upon the plants, viz, *Puccinia rubigo-vera* on nearly every leaf, *Puccinia graminis* on an occasional stalk, and *Septoria graminum* on many of the leaves, but causing no serious damage.

Plats 2 and 67, 4 and 69, 6 and 71.—Soil treatment with flowers of sulphur; yield of both straw and wheat above the average, but the red rust was noticeable on every plant, not, however, in destructive quantities, as the wheat was full and plump.

Plats 8 and 73, 10 and 75.—Soil treatment with sulphur and lime; showed the usual amount of rust, with an average product of wheat and straw.

Plats 12 and 77.—Soil treatment with sulphate of iron; showed the rust in average quantities and yielded a medium amount of grain.

Plats 14 and 79.—Soil treatment with ferrous sulphate in water; did not show as good results in yield as 12 and 77. The usual amount of rust was present.

Plats 16 and 81.—Soil treatment with Bordeaux mixture; showed normal amount of rust, and the yield fell considerably below the average.

Plats 18 and 83.—Soil treatment with sulphide of potassium solution; showed the usual mount of rust and yielded below the average.

Plats 20 and 85.—Soil treatment with ammoniacal solution of copper carbonate; seemed to produce a bad effect on the germination of the seed, as the stand was thin, badly rusted, and the yield much below the average.

Plats 22 and 87.—Hot-water treatment of seed; showed normal amount of rust and decreased yield.

Plats 24 and 89.—Seed treated by immersing for twenty-four hours in 8:100 solution of copper sulphate, then limed; showed usual amount of rust and a yield lower than the adjoining untreated plats.

Plats 26 and 91.—Seed treated by immersing for twenty-four hours in Bordeaux mixture; gave fairly good average results, but was rusted.

Plats 28 and 93.—Seed treated by immersing for twenty-four hours in a 5:100 solution of potassium bichromate; badly rusted and yield lower than the average.

Plats 30 and 95.—Seed treated by immersing for twenty-four hours in potassium sulphide solution; produced fair results, though rusted as usual.

Plats 32 and 97.—Treated the same as the preceding, but with solution only half as strong; yielded a very inferior crop, which was badly rusted.

Plats 34 and 100.—Seeds treated by immersing for twenty-four hours in 1:1000 solution of corrosive sublimate; injured the vitality of the seed and gave a very light yield, with usual amount of rust.

Plats 36 and 102.—Sprayed with Bordeaux mixture every ten days from October 28 until June 24; yielded above the average and were not nearly so badly rusted as the preceding numbers or as the adjoining untreated plats.

Plats 38 and 104.—Sprayed every ten days with ammoniacal solution of copper carbonate; also yielded in excess of the average and were very slightly rusted.

Plats 40 and 106.—Sprayed every ten days with sulphide of potassium solution, 2 ounces to 3 gallons of water; did not show as good results, yet produced better yields than the adjoining untreated plats, being more free from rust but not so free as the two preceding groups.

Plats 42 and 108.—Sprayed every twenty days with Bordeaux mixture; yielded results very similar to plats 36 and 102, but showed more rust.

Plats 44 and 110.—Sprayed every twenty days with ammoniacal solution; was not so successful as plats 38 and 104, treated every ten days with the same preparation.

Plats 46 and 112.—Sprayed every twenty days with potassium sulphide solution; gave little or no effect in preventing rust, but yielded better than the adjoining untreated plats.

Plats 48 and 114.—Seed, soil, and spraying treatments with Bordeaux mixture; seed immersed twenty-four hours, soil treated with one-half gallon to 20 feet of row, and plants sprayed every ten days. This treatment was well nigh fatal, giving the lightest yield of any group in the whole tract; very little rust.

Plats 50 and 116.—The treatment of these plats was exactly the same as the preceding, only potassium sulphide was used instead of Bordeaux mixture. The results were very unsatisfactory and the yield light; very little rust.

Plats 52 and 118.—Seed, soil, and spraying treatments with ammoniacal solution of copper carbonate; plants sprayed every ten days and soil treated with 2 gallons of the solution to 20 feet of row; not much rusted; yield normal.

Plats 54 and 120.—Seed and spraying treatment, the latter every ten days with Bordeaux mixture, the former with hot water; slightly rusted; very similar to the preceding group.

Plats 56 and 122.—Seed and soil treatment; hot-water treatment for seed; 2 ounces flowers of sulphur and 2 ounces air-slaked lime mixed to 20 feet of row for soil. The yield was about up to the average, but no appreciable lessening of the rust could be detected.

Plats 58 and 124.—Seed and soil treatment; hot-water treatment for seed; 2½ ounces ferrous sulphate to 25 feet of row for soil; normal yield, but no diminution of rust.

The following plats, as already indicated, were held for spring treatment:

Plats 60 and 126.—Sprayed with Bordeaux mixture; the yield was good and the rust was considerably less than on the adjoining untreated plats.

Plats 62 and 128.—Sprayed on the same dates as the last 2 plats, with ammoniacal carbonate of copper solution; very similar to the preceding group in all respects.

Plats 64 and 130.—Sprayed at the same time as 62 and 128, with potassium sulphide solution, 2 ounces to 3 gallons of water; this spraying was deleterious and decreased the yield noticeably; it had little effect in preventing rust.

In the following table is shown the yield of straw and grain for each plat and its duplicate:

TABLE 8.—*Showing kind of treatment and yield of grain and straw.*

Plat.	Kind of treatment.	Yield of grain and straw.		Yield of cleaned grain.	
		Lbs.	*Oz.*	*Lbs.*	*Oz.*
1 and 66	Untreated	11	2	2	2
	do	9	9	1	10
2 and 67	Soil treatment with flowers of sulphur, 5 ounces to 25 feet of row	12	12	3	2
		11	4	2	12
3 and 68	Untreated	9	12	1	12
	do	9	6	1	12
4 and 69	Soil treatment with flowers of sulphur, 2½ ounces to 25 feet of row	11	14	2	6
		11	4	2	4
5 and 70	Untreated	10	13	2	0
	do	10	13	1	14
6 and 71	Soil treatment with flowers of sulphur, 1¼ ounces to 25 feet of row	12	0	2	8
		11	8	2	4
7 and 72	Untreated	10	4	2	2
	do	10	0	2	0
8 and 73	Soil treatment with lime and sulphur, equal parts mixed, 5 ounces to 25 feet of row	10	10	2	6
		10	5	2	2
9 and 74	Untreated	9	0	1	10
	do	9	9	2	0
10 and 75	Soil treatment with lime and sulphur, equal parts mixed, 2½ ounces to 25 feet of row	13	5	2	8
		11	4	2	2
11 and 76	Untreated	9	14	1	12
	do	10	10	1	12
12 and 77	Soil treatment with powdered ferrous sulphate, 5 ounces to 25 feet of row	10	0	1	10
		11	6	2	2

TABLE 8.—*Showing kind of treatment and yield of grain and straw*—Continued.

Plat.	Kind of treatment.	Yield of grain and straw.		Yield of cleaned grain.	
		Lbs.	*Oz.*	*Lbs.*	*Oz.*
13 and 78	Untreated	12	4	2	4
	do	11	6	2	0
14 and 79	Soil treatment with 5 pints of water containing 5 ounces of ferrous sulphate to 25 feet of row	9	2	1	8
		9	14	1	12
15 and 80	Untreated	10	4	1	14
	do	9	10	1	10
16 and 81	Soil treatment with 5 pints of Bordeaux mixture to 25 feet of row	9	6	1	15
		9	4	1	15
17 and 82	Untreated	10	6	2	0
	do	9	8	1	12
18 and 83	Soil treatment with 5 pints of water containing 1¼ ounces of potassium sulphide to 25 feet of row	9	8	1	10
		10	8	1	12
19 and 84	Untreated	10	10	1	14
	do	8	12	1	8
20 and 85	Soil treatment with 5 pints of ammoniacal solution of copper carbonate to 25 feet of row	7	10	1	6
		9	8	1	12
21 and 86	Untreated	10	8	1	14
	do	10	4	1	15
22 and 87	Seed immersed in water at 133° F. for 15 minutes	7	8	1	9
		10	12	2	0
23 and 88	Untreated	10	12	2	2
	do	10	6	2	0
24 and 89	Seed immersed in an 8:100 solution of copper sulphate for 24 hours, then limed	7	10	1	6
		10	0	1	14
25 and 90	Untreated	11	0	2	6
	do	10	12	2	5
26 and 91	Seed immersed for 24 hours in Bordeaux mixture	11	0	2	6
		11	0	2	4
27 and 92	Untreated	10	0	2	0
	do	10	4	2	3
28 and 93	Seed immersed for 24 hours in a 5:100 solution of potassium bichromate	9	0	2	0
		9	8	2	2
29 and 94	Untreated	10	10	2	5
	do	10	0	2	0
30 and 95	Seed immersed for 24 hours in a solution of potassium sulphide, 1 ounce to 1 gallon of water	10	2	2	2
		10	4	2	6
31 and 96	Untreated	11	8	2	6
	do	11	0	2	0
32 and 97	Seed immersed for 24 hours in a solution of potassium sulphide, ½ ounce to 1 gallon of water	8	4	1	10
		8	0	1	12
32½ and 98	Untreated	11	6	2	2
	do	11	4	2	4
33 and 99	do	10	3	2	2
	do	9	12	1	13
34 and 100	Seed immersed for 24 hours in a 1:1000 solution of corrosive sublimate	9	10	1	14
		5	9	1	2
35 and 101	Untreated	10	9	2	4
	do	10	6	2	4
36 and 102	Plants sprayed every 10 days with Bordeaux mixture	11	13	2	12
		11	6	2	3
37 and 103	Untreated	11	2	2	0
	do	9	12	1	12
38 and 104	Plants sprayed every 10 days with ammoniacal solution of copper carbonate	12	2	2	8
		10	12	2	6
39 and 105	Untreated	9	12	1	10
	do	10	8	2	2
40 and 106	Plants sprayed every 10 days with potassium sulphide solution, 2 ounces to 3 gallons of water	10	10	2	1
		10	12	2	6
41 and 107	Untreated	9	12	1	11
	do	10	4	1	12
42 and 108	Plants sprayed every 20 days with Bordeaux mixture	12	4	2	8
		10	10	2	4
43 and 109	Untreated	9	10	1	11
	do	11	4	2	5
44 and 110	Plants sprayed with ammonical solution of copper carbonate every 20 days	10	8	1	12
		9	14	1	12
45 and 111	Untreated	9	6	1	14
	do	9	6	1	10
46 and 112	Plants sprayed with potassium sulphide solution, 2 ounces to 3 gallons of water every 20 days	10	4	1	12
		9	6	1	9
47 and 113	Untreated	8	2	1	5
	do	8	12	1	7
48 and 114	Seed, soil, and spraying treatments; seed immersed in Bordeaux mixture 24 hours; soil treated with 5 pints of Bordeaux mixture to 25 feet of row; plants sprayed with Bordeaux mixture every 10 days	6	2	1	4
		5	2	1	0
49 and 115	Untreated	10	8	2	0
	do	9	12	1	14

TABLE 8.—*Showing kind of treatment and yield of grain and straw*—Continued.

Plat.	Kind of treatment.	Yield of grain and straw.		Yield of cleaned grain.	
		Lbs.	*Oz.*	*Lbs.*	*Oz.*
50 and 116	Seed, soil, and spraying treatments with potassium sulphide solution 2 ounces to 3 gallons of water; seed immersed for 24 hours; soil treated with 5 pints to 25 feet of row; plants sprayed every 10 days	7	12	1	6
		6	7	1	2
51 and 117	Untreated	10	0	1	12
	do	10	4	1	10
52 and 118	Seed, soil, and spraying treatments; seed immersed for 24 hours in ammoniacal solution of copper carbonate; plants sprayed every 10 days with the same preparation	9	14	2	0
		10	12	2	5
53 and 119	Untreated	10	6	2	0
	do	9	0	1	11
54 and 120	Seed and spraying treatments; seed immersed for 15 minutes in water at 133° F.; plants sprayed every 10 days with Bordeaux mixture	10	4	2	4
		9	2	1	9
55 and 121	Untreated	10	2	1	14
	do	10	4	2	5
56 and 122	Seed and soil treatment; seed immersed for 15 minutes in water at 133° F.; soil treated with lime and sulphur, equal parts, 5 ounces to 25 feet of row	10	6	1	8
		11	12	1	14
57 and 123	Untreated	11	0	2	3
	do	10	10	2	4
58 and 124	Seed and soil treatments; seed immersed in water at 133° F. for 15 minutes; soil treated with 2½ ounces of ferrous sulphate to 25 feet of row	10	4	2	2
		10	6	2	0
59 and 125	Untreated	10	8	2	3
	do	10	10	2	6
60 and 126	Reserved for spring treatments, but sprayings were not made	10	14	2	8
		10	12	2	9
61 and 127	do	10	0	1	14
	do	10	12	2	4
62 and 128	do	10	4	2	1
	do	11	4	2	4
63 and 129	do	11	8	2	6
	do	11	0	2	1
64 and 130	do	9	8	1	8
	do	10	0	1	13
65 and 131	do	11	4	2	3
	do	9	10	1	12

In commenting upon this table, Mr. Bartholomew says:

The total weight of straw and grain on the entire tract was 1,528 pounds, the 62 untreated plats yielding 797 pounds, and the 58 treated ones 731 pounds. The average yield per plat for the former was 11.72 pounds and for the latter 11.32 pounds. The total yield of cleaned grain was 258 pounds, being 133 pounds for the untreated and 125 pounds for the treated.

The average yield on both classes was almost exactly the same, viz, 1.95 pounds per plat. This shows a difference in favor of the treated plats in the matter of grain when we consider that the average product of these plats was about one-third of a pound less per plat, and that a number of the plats were greatly injured by the treatment as indicated in the table, showing a marked decrease in the production of both grain and straw. Doing away with the passage ways between the plats and presuming the rows to be 9 inches apart over the whole tract, this would indicate a yield of about 17 bushels per acre, which is in marked contrast with the adjoining field, where the yield was 30 bushels. Of course in the field the conditions were quite different. The seed was sown broadcast among cornstalks and thoroughly cultivated in with a fine shovel cultivator, and stood very thick all over the ground.

Another rather peculiar thing must be noted regarding conditions. The preparation of the ground consisted in cultivating and thoroughly harrowing the land, which placed it in excellent condition for seeding. A good crop of corn was raised on the land. This was cut and carried off before the cultivating and harrowing. The whole plat was very smooth, so much more so, in fact, than the adjoining field, that it proved an excellent playground for dozens of jack rabbits. Many of the young plants were

actually pulled out by the roots by these animals. Had it not been for this aggravating cause I have no doubt that the yield in straw and grain would have reached an average of 13 pounds per plat.

My conclusions regarding the efficacy of the various treatments are easily drawn. I have little hesitancy in saying that the several soil and seed treatments, so far as the prevention of rusts are concerned, were practically valueless. The sulphur treatments were productive of good results in an increase of yield but with that the matter stops. The success, whatever there is of it, has been all attained through sprayings. While it is true that no plat was entirely free from rust, it is nevertheless a fact that its ravages were reduced to a minimum on the ten-day plats sprayed with Bordeaux mixture and ammoniacal solution of copper carbonate. I think the potassium sulphide solution should be discarded, as it seems to have a deleterious effect wherever applied. This was especially apparent, as will be noted, in Experiment B. Last fall I thought that the Bordeaux mixture when applied to very young plants had a deleterious effect, but my observations this season have led me to conclude that when properly applied no harm follows.

Experiment B.

The object of this work was to test the effect of eleven preparations as preventives of rust when applied to spring wheat and oats in the form of spray beginning when rust first appeared. The preparations used were as follows:*

Table 9.—*Showing the composition of the fungicides used.*

No. 26	Basic cupric acetate mixture:	
	Cupric acetate (refined powder)	47.6 grams.
	Water	15144.0 grams.
No. 27	Copper borate mixture:	
	Cupric sulphate	59.6 grams.
	Sodium borate (borax)	65.5 grams.
	Water	15144.0 grams.
No. 28	Cupric ferrocyanide mixture:	
	Cupric sulphate	59.6 grams.
	Potassium ferrocyanide (yellow prussiate of potash)	89.4 grams.
	Water	15144.0 grams.
No. 29	Cupric hydroxide mixture:	
	Cupric sulphate	59.6 grams.
	Potassium hydrate	107.2 grams.
	Water	15144.0 grams.
No. 30	Tricupric orthophosphate mixture:	
	Cupric sulphate	59.6 grams.
	Sodium phosphate	104.2 grams.
	Water	15144.0 grams.
No. 31	Cupric polysulphide mixture:	
	Cupric sulphate	59.6 grams.
	Potassium sulphide (liver of sulphur)	59.6 grams.
	Water	15144.0 grams.
No. 32	Ferrous ferrocyanide mixture:	
	Ferrous sulphate exsiccatus	91.7 grams.
	Potassium ferrocyanide	183.5 grams.
	Water	15144.0 grams.
No. 33	Iron borate mixture:	
	Ferrous sulphate exsiccatus	91.7 grams.
	Sodium borate (borax)	367.0 grams.
	Water	15144.0 grams.
No. 34	Iron sulphide mixture:	
	Ferrous sulphate exsiccatus	91.7 grams.
	Potassium sulphide (liver of sulphur)	367.0 grams.
	Water	15144.0 grams.
No. 35	Zinc borate mixture:	
	Zinc sulphate	133.4 grams.
	Sodium borate (borax)	133.4 grams.
	Water	15144.0 grams.
No. 38	Bordeaux mixture, weak strength:	
	Cupric sulphate	10.4 grams.
	Lime (stone)	2.5 grams.
	Water	15144.0 grams.

*The numbers here are the original ones given by my assistants to the preparations for convenience of reference.

In addition to the foregoing there was one soil and seed treatment with Bordeaux mixture, the seed being immersed for twenty-four hours in the preparation and the soil treated with one-half gallon of the mixture to 20 feet of row. For the experiment as a whole 100 plats, each 3 by 15 feet, were used. Fifteen of the plats were planted with wheat and the same number with oats. For seed, White Mediterranean wheat, and Black Winter oats were used, each being planted on April 8, 1892. On June 4 *Puccinia rubigo-vera* was noticed on a few plants of wheat, thereupon each plat received the following treatment:

TABLE 10.—*Showing kind of treatment given each plat in Experiment B.*

Plat.	Kind of treatment.
1 and 1	No treatment.
26 and 26	Sprayed with basic cupric acetate mixture.
2 and 2	No treatment.
27 and 27	Sprayed with copper borate mixture.
3 and 3	No treatment.
28 and 28	Sprayed with cupric ferrocyanide mixture.
4 and 4	No treatment.
29 and 29	Sprayed with cupric hydroxide mixture.
5 and 5	No treatment.
30 and 30	Sprayed with tricupric orthophosphate mixture.
6 and 6	No treatment.
31 and 31	Sprayed with cupric polysulphide mixture.
7 and 7	No treatment.
32 and 32	Sprayed with ferrous ferrocyanide mixture.
8 and 8	No treatment.
33 and 33	Sprayed with iron borate mixture.
9 and 9	No treatment.
34 and 34	Sprayed with iron sulphide mixture.
10 and 10	No treatment.
35 and 35	Sprayed with zinc borate mixture.
11 and 11	No treatment.
38 and 38	Sprayed with Bordeaux mixture.
12 and 12	No treatment.
24 and 24	Soil and seed treatment with Bordeaux mixture.

Additional sprayings were made on June 6, 16, and 20, and July 5, respectively. The oats were harvested on July 16 and the wheat two days later. Mr. Bartholomew furnished the following notes on the effect of each treatment, the numbers given being those of the preparation and not the plats:

The condition of the untreated plats with respect to rust was very similar to those in Experiment A, all being quite uniformly affected with the fungus. The total yield for the 26 untreated plats was as follows:

Straw and grain	pounds..	89½
Cleaned grain	do....	13¾
Straw and grain per plat	do....	3⅓
Cleaned grain per plat	ounces..	8½

No. 26.—Basic cupric acetate mixture. Almost *entirely* free from rust; yield considerably above the average, viz, 4 pounds, and 4 pounds, 10 ounces per plat. The adjoining untreated plats were covered with red rust from bottom to top.

No. 27.—Copper borate mixture. Very similar to 26, being free from rust and the yield above the average.

No. 28.—Cupric ferrocyanide mixture. Below the average in yield, being injured by the fungicide; straw and grain light; can not recommend this preparation.

No. 29.—Cupric hydroxide mixture. Yield above the average and remarkably free from rust.

No. 30.—Tricupric orthophosphate mixture. The same as the last.

No. 31.—Cupric polysulphide mixture. Quite free from rust and produced the best yield on the tract, viz, 4 pounds, 8 ounces, and 4 pounds, 10 ounces per plat.

No. 32.—Ferrous ferrocyanide mixture. A practical failure, yielding very lightly in straw and almost no grain. This preparation should certainly be discarded. It is, however, a good weed destroyer, and would be good where weeds or grass are to be kept permanently down about trees or shrubs. No weeds came up on these plats after harvest, while on all the rest more or less weeds appeared.

No. 33.—Iron borate mixture. Yield normal, but plats considerably rusted. Would not recommend this preparation.

No. 34.—Iron sulphide mixture. A decided failure, producing very unsatisfactory results. If full strength had been used scarcely a green stalk would have been left by the fourth spraying, but after the second spraying the preparation was used half strength and was even then too severe. Very little rust.

No. 35.—Zinc borate mixture. Yield good; quite free from rust, though not as perfectly free as some of the preceding numbers.

No. 38.—Bordeaux mixture. Yield of straw good, but grain light. My experience with Bordeaux is that it has a decided effect on the common red rust as indicated, not only in this experiment, but in "A" also. These plats were nearly free from rust.

No. 24.—Seed immersed 24 hours in Bordeaux; one-half gallon of the mixture to 20 feet of row for soil; treatment showed as much rust as any untreated plat. The product was above the average in straw and grain.

One thing particularly noticeable at the time of threshing was the fact that in such treatments as 26, 27, 29, 30, 31, and 38 the lower leaves were full and abundant, while in the untreated plats they were mostly thin, shrunken, or fallen off. Could these results be made to obtain throughout a field, it occurs to me that the feeding value of a ton of straw would be greatly increased. As a whole, these experiments were far more satisfactory than those described under "A."

In the following table the yield of the several treated spring wheat plats is given:

TABLE 11.—*Showing method of treatment and yield of grain and straw.*

Plat.	Kind of treatment.	Yield of grain and straw.		Yield of cleaned grain.
		Pounds.	*Ounces.*	*Ounces.*
26 and 26	Sprayed with basic cupric acetate mixture	4	0	10
		4	10	12
27 and 27	Sprayed with copper borate mixture	4	3	9
		4	6	9
28 and 28	Sprayed with cupric ferrocyanide mixture	3	2	6
		3	8	8
29 and 29	Sprayed with cupric hydroxide mixture	3	12	8
		4	0	9
30 and 30	Sprayed with tricupric orthophosphate mixture	4	0	9
		4	4	11
31 and 31	Sprayed with cupric polysulphide mixture	4	10	10
		4	8	11
32 and 32	Sprayed with ferrous ferrocyanide mixture	3	4	7
		3	0	6
33 and 33	Sprayed with iron borate mixture	3	0	7
		3	8	8
34 and 34	Sprayed with iron sulphide mixture	3	6	7
		3	3	6
35 and 35	Sprayed with zinc borate mixture	4	2	10
		3	12	10
38 and 38	Sprayed with Bordeaux mixture	3	14	8
		4	6	9
24 and 24	Soil and seed treatment with Bordeaux mixture	4	2	9
		3	10	8

It appears from the foregoing that the total yield of straw and grain on the 24 treated plats was 82 pounds, an average of 3.41 pounds per plat. The total yield of cleaned grain was 13 pounds, an average of 8¾ ounces per plat. The total averages in this case do not differ materially from those where no treatments were made. It should be borne in mind, however, that there were 2 more plats in the untreated lot than in the treated; also, that a number of the treated plats were so seriously injured that the yield was very light. Taking out of consideration the reduction in the crop due to the foregoing causes, the treated plats gave a somewhat higher average yield than the untreated.

The results in the treatment of oats were wholly negative, as no rust whatever appeared on any of the plats. It may be of interest to say, however, that several of the preparations, notably Nos. 32 and 35, seriously injured the plants. As a result of this the yield of the treated plats was nearly 10 per cent less than the untreated.

Experiment C.

Experiment C consisted of spraying 1 plat each of late-planted spring wheat and oats with Bordeaux mixture, full strength, combined with soap. It was thought that possibly rust would not appear in experiments A and B; consequently the late spring grains, which are almost invariably attacked by the disease, were put in. Each plat was 33 feet long and 3 feet wide, there being 2 in each case, 1 for treatment and 1 for control. The sowing was not done until May 20, but the weather was so warm that the plants were well up by the 30th of the same month. Six treatments in all were made, the dates being May 30, June 3, 6, 16, and 25, and July 5, respectively. No rust of consequence appeared on any of the plats, consequently the results so far as concerned the prevention of this disease were negative.

CONCLUSION.

The work described in the foregoing pages, carried on under widely different conditions of soil and climate, seems to clearly indicate that treating the seed and soil previous to planting with various chemicals and with hot water is of no value whatever so far as the prevention of rust is concerned. This accords with our knowledge of the life history of the rust fungi attacking cereals, and bears out the generally accepted belief of those who have studied the matter. Many of the soil and seed treatments were positively injurious, diminishing the crop to a far greater extent than all the diseases observed combined.

The spraying treatments did, in some cases at least, diminish the amount of rust and seemingly increased the yield of straw and grain. A slight increase of yield in an experiment of this kind, however, must be looked upon with a good deal of suspicion, as there are many things that might influence the matter one way or another. On the whole

there seems no good reason for believing that spraying, even with the most improved methods with which we are now familiar, would be practicable or profitable on a large scale. At Garrett Park, where this kind of work was done with the greatest care and where every precaution was taken to make the various preparations cover the foliage, rust was just as abundant on the sprayed as on the unsprayed wheat. A critical study of the plants in the field afforded what seems a satisfactory explanation of the foregoing fact. On examining the leaves immediately after they had been sprayed in the most careful manner, it was found that fully one-half of the surface was wholly free from any signs of the liquid put on. The shape of the leaf, its position on the stem, manner of growth, and waxy covering, all conspire to render it exceedingly difficult to wet, and unless thoroughly wetted or covered by the fungicide there is little hope of preventing the reproductive bodies of the rust fungi from gaining an entrance.

Finally, it may be said that while improved machinery and fungicides and improved methods may make it possible to profitably spray our cereals, with our present means this can not be done. The work, however, should not be abandoned; on the contrary, it should be continued until the matter is definitely settled one way or the other. At the same time the far more promising work of breeding rust-resisting varieties should be taken up and carried forward along such lines as offer the most promising results.

ADDITIONAL NOTES ON PEACH ROSETTE.

By Erwin F. Smith.

I.—SPREAD OF THE DISEASE.

The peach rosette continues in Georgia and has appeared in South Carolina. Mr. W. L. Anderson, of Ninety-six, sent specimens from his peach orchard, and wrote as follows, under date of June 14, 1892:

> In the summer of 1890 I noticed some of the peach trees turning yellow; but, from information at hand, concluded it was not what is called the yellows. The trees (3) died, root and branch. No sprouts have ever put forth from the old roots of any of these or other trees since attacked. Last year I lost 6 trees from the same disease. This year I cut down 8 as soon as I noticed the peculiar growth of the leaves. I have 2 left, some one-fourth mile apart. They are, at this writing, evidently moribund and will be dead in another month.

Mr. Anderson states that several of his neighbors have lost trees, and that the disease is entirely new to him, although he has lived in that region and been interested in peach-growing for a long time.

Some field work begun in Georgia in 1890 and 1891, could not be reported upon fully in Bulletin 1,* because incomplete or only just begun

*Div. Veg. Pathology, U. S. Dept. of Agr., 1891.